Low Complexity And Power Allocation For Random Access With Layered Reambles Based on Noma In MTC

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Abstract- *In machine-type communication (MTC), random access has been employed for a number of devices and sensors to access uplink channels using a pool of preambles. To support different priorities due to various quality-of-service (QoS) requirements, random access can be generalized with multiple pools, which may result in low spectral efficiency. For high spectral efficiency, random access with layered preambles (RALP) is proposed to support devices with two different priorities based on the notion of power-domain nonorthogonal multiple access (NOMA). In RALP, two groups of devices, namely type-1 and type-2 devices, are supported with different priorities, where type-1 devices have higher priority than type-2 devices. Closed-form expressions are derived for the detection performance of preambles transmitted by type-1 devices, which can be used for a certain performance guarantee of type-1 devices of high priority.*

Keywords- machine-type communication, quality-of-service, nonorthogonal multiple access,

I. INTRODUCTION

The Internet of Things (IoT) is a network of things that are connected for a number of applications including smart cities and factories. To support the connectivity, a number of different approaches have been proposed. For example, low-power wide area networks (LPWAN) are studied to support devices with long range communications in unlicensed bands. Cellular IoT using machine-type communication (MTC) is also considered to support the connectivity of IoT devices and sensors in cellular systems. In, a deployment study of narrowband IoT (NB-IoT) is presented for IoT applications with sensors and devices deployed over a large area within a cellular system.

Due to sparse activity and sporadic traffic of devices and sensors in MTC, random access is used to keep signaling overhead low, and various random access schemes with a set of preambles are studied in handshaking process to establish connections.

To support a large number of devices with limited bandwidth, non-orthogonal preambles can be used and the detection of non-orthogonal preambles can be carried out using multiuser detection approaches. Since a fraction of devices are active at a time, the sparse user activity can be taken into account to design multiuser detectors. The sparse user activity can be represented by a sparse vector so that the resulting random access can be seen as a sparse signal recovery problem in the context of compressive sensing (CS), which is called compressive random access. Compressive random access can be used for grantfree random access and be combined with massive multiple-input multiple-output (MIMO).

For example, each active device has the same probability of preamble collision. As a result, no priority is introduced in conventional compressive random access. However, as in, devices can have different priorities depending on their Quality-of-Service (QoS) requirements.

To support different priorities, in this paper, we consider random access with layered preambles (RALP) based on the notion of power-domain non-orthogonal multiple access (NOMA). In particular, the main contributions are it is assumed that there are two different types of devices in terms of priority, namely type-1 and type-2 devices, where type-1 devices have higher priority than type-2 devices, while the number of active type-1 devices is much fewer than that of active type-2 devices. In RALP, it is aimed that the probability of detection errors of type-1 devices is to be sufficiently low, while that of type-2 devices is arbitrary. In summary, the main contributions of the paper are as follows: i) using layered preambles based on power-domain NOMA, a random access scheme to support two different types of devices is proposed; ii) a low-complexity preamble detection approach is derived using successive interference cancellation (SIC) and a wellknown machine learning algorithm, i.e., a variational inference (VI) algorithm; iii) closed-form expressions for preamble detection error probabilities of type-1 devices are derived.

There are a number of related works. For example, in [21], layered preambles are also considered using the notion of power-domain NOMA, while different priorities are not taken into account. In terms of supporting two different priorities in MTC, [28] is the most related work, which mainly focuses on dynamic resource allocation and user barring without using layered preambles. In fact, since RALP in this paper can provide different priorities with layered preambles and different detection performance, it can be used within dynamic resource allocation and user barring schemes, which can be seen as a further work.

Non-orthogonal multiple access (NOMA) has become an important principle for the design of radio access techniques for the fifth generation (5G) wireless networks. Although several 5G multiple access techniques have been proposed by academia and industry, including power domain NOMA, sparse code multiple access (SCMA) pattern division multiple access (PDMA) low density spreading (LDS) and lattice partition multiple access (LPMA) these techniques are based on the same key concept, where more than one user is served in each orthogonal resource block, e.g., a time slot, a frequency channel, a spreading code, or an orthogonal spatial degree of freedom. Unlike NOMA, conventional orthogonal multiple access (OMA) techniques, such as time division multiple access (TDMA) and orthogonal frequency division multiple access (OFDMA), serve a single user in each orthogonal resource block.

The spectral inefficiency of OMA can be illustrated with the following simple example. Consider a scenario, where one user with very poor channel conditions needs to be served for fairness purposes, e.g., this user has high priority data or has not been served for a long time. In this case, the use of OMA means that it is inevitable that one of the scarce bandwidth resources is solely occupied by this user, despite its poor channel conditions. Obviously, this has a negative impact on the spectrum efficiency and throughput of the overall system. In such a situation, the use of NOMA ensures not only that the user with poor channel conditions is served but also that users with better channel conditions can concurrently utilize the same bandwidth resources as the weak user. As a result, if user fairness has to be guaranteed, the system throughput of NOMA can be significantly larger than that of OMA. In addition to its spectral efficiency gain, academic and industrial research has also demonstrated that NOMA can effectively support massive connectivity, which is important for ensuring that the forthcoming 5G network can support the Internet of Things (IoT) functionalities. Although the application of NOMA in cellular networks is relatively new, related concepts have been studied in information theory for a long time. For example, key components of NOMA, such as superposition coding, successive interference cancellation (SIC), and the message passing algorithm (MPA), have already been invented more than two decades ago.

Nevertheless, the principle of NOMA, i.e., removing orthogonality, has not been used in the previous generations of cellular networks. In this content, we note that the philosophy behind 3 NOMA is rarther different from that behind code division multiple access (CDMA). In fact, CDMA is primarily built upon the idea that users are separated by exploiting the differences among their spreading codes, whereas NOMA encourages multiple users to employ exactly the same code. As a consequence, for CDMA, the chip rate has to be much higher than the supported information data rate,

NOMA overcomes the near-far problems of the 3G systems and improves the fairness in resource allocation in the 4G systems. NOMA is a multi-user multiplexing scheme that exploits the frequency domain, time domain, and power domain similarly. Compared with the traditional orthogonal transmission, NOMA uses non-orthogonal transmission at the sending terminals, introducing interference information deliberately, and realizes the demodulation by the successive interference cancellation (SIC) technology at the receiving terminals. NOMA technologies can still use the OFDM symbol as the smallest unit in the time domain, and insert the cycle prefix (CP) between the symbols to prevent inter-symbol interference (ISI). While, in the frequency domain, the smallest units can still be the sub-channels, and OFDM technologies are used in each sub channels to keep the sub-channels are orthogonal and non-interference with each other. However, the power of each sub-channel and the OFDM symbol is shared by multiple users instead of only for one user. In particular, the signal power of different users on the same sub channel and OFDM symbol is non-orthogonal, which led to MAI for shared channels. In order to overcome the interference, NOMA at the receiver using a SIC technology for multi-user interference detection and deletion to ensure the normal communication of the systems. Thus, the receiver complexity of NOMA has improved compared with orthogonal transmission, but it can get higher spectral efficiency

II. LITERATURE SURVEY

Low Guan Gui; et al., (2018) proposed a novel and effective deep learning (DL)-aided NOMA system, in which several NOMA users with random deployment are served by one base station (BS). Since DL is advantageous in that it allows training the input signals and detecting sharply changing channel conditions, we exploit it to address wireless NOMA channels in an end-to-end manner. Specifically, it is employed in the proposed NOMA system to learn a completely unknown channel environment. A long short-term memory (LSTM) network based on DL is incorporated into a typical NOMA system, enabling the proposed scheme to detect the channel characteristics automatically. In the proposed strategy, the LSTM is first trained by simulated data under different channel conditions via offline learning, and then the corresponding output data can be obtained based on the current input data used during the online learning process. In general, we build, train and test the proposed cooperative framework to realize automatic encoding, decoding and channel detection in an additive white Gaussian noise (AWGN) channel.

Luca Sanguinetti et al., (2018) work advocates the use of deep learning to perform max-min and max-prod power allocation in the downlink of Massive MIMO networks. More precisely, a deep neural network is trained to learn the map between the positions of user equipments (UEs) and the optimal power allocation policies, and then used to predict the power allocation profiles for a new set of UEs' positions. The use of deep learning significantly improves the complexity-performance trade-off of power allocation, compared to traditional optimization-oriented methods. Particularly, the proposed approach does not require the computation of any statistical average, which would be instead necessary by using standard methods, and is able to guarantee near-optimal performance.

Md Shipon Ali, Hina Tabassum et al., (2016) presents Non-Orthogonal Multiple Access (NOMA) has recently been considered as a key enabling technique for 5G cellular systems. In NOMA, by exploiting the channel gain differences, multiple users are multiplexed into transmission power domain and then non-orthogonally scheduled for transmission on the same spectrum resources. Successive interference cancellation (SIC) is then applied at the receiver(s) to decode the message signals. In this paper, first briefly describe the differences in the working principles of uplink and downlink NOMA transmissions in a cellular wireless system. Then, for both uplink and downlink NOMA, formulate a sum-throughput maximization problem in a cell such that the user clustering (i.e., grouping users into a single cluster or multiple clusters) and power allocations in NOMA cluster(s) can be optimized under transmission power constraints, minimum rate requirements of the users, and SIC constraints. Due to the combinatorial nature of the formulated mixed integer non-linear programming (MINLP) problem, we solve the problem in two steps, i.e., by first grouping users into clusters and then optimizing their respective power allocations. In particular, propose a low-complexity sub-optimal user grouping scheme. The proposed scheme exploits the channel gain differences among users in a NOMA cluster and groups them into a single cluster or multiple clusters in order to enhance the sumthroughput of the system. For a given set of NOMA clusters, we then derive the optimal power allocation policy that maximizes the sum-throughput per NOMA cluster and in turn maximizes the overall system throughput. Using KKT optimality conditions, closed-form solutions for optimal power allocations are derived for any cluster size, considering both uplink and downlink NOMA systems. Numerical results compare the performances of NOMA and orthogonal multiple access (OMA) and illustrate the significance of NOMA in various network scenarios.

Xinyu Gao et al., (2016) proposed Millimeter wave (mmWave) MIMO will likely use hybrid analog and digital precoding, which uses a small number of RF chains to reduce the energy consumption associated with mixed signal components like analog-to-digital components not to mention baseband processing complexity. However, most hybrid precoding techniques consider a fully-connected architecture requiring a large number of phase shifters, which is also energyintensive. In this paper, focus on the more energy-efficient hybrid precoding with sub-connected architecture, and propose a successive interference cancelation (SIC)-based hybrid precoding with near-optimal performance and low complexity. Inspired by the idea of SIC for multi-user signal detection, we first propose to decompose the total achievable rate optimization problem with non-convex constraints into a series of simple sub-rate optimization problems, each of which only considers one subantenna array. Then, we prove that maximizing the achievable sub-rate of each sub-antenna array is equivalent to simply seeking a precoding vector sufficiently close (in terms of Euclidean distance) to the unconstrained optimal solution. Finally, propose a low-complexity algorithm to realize SIC-based hybrid precoding, which can avoid the need for the singular value decomposition (SVD) and matrix inversion. Complexity evaluation shows that the complexity of SIC-based hybrid precoding is only about 10% as complex as that of the recently proposed spatially sparse precoding in typical mmWave MIMO systems. Simulation results verify that SIC-based hybrid precoding is near-optimal and enjoys higher energy efficiency than the spatially sparse precoding and the fully digital precoding.

Muhammad et al., (2012) address the optimal source, relay, and receive matrices design for linear non-regenerative uplink multiuser multiple-input multiple-output (MIMO) relay communication systems. The minimum mean-squared error (MMSE) of the signal waveform estimation at the destination node is adopted as our design criterion. We develop two iterative methods to solve the highly nonconvex joint source, relay, and receiver optimization problem. In particular, we show that for given source precoding matrices, the optimal relay amplifying matrix diagonalizes the source-relay-destination channel. While for fixed relay matrix and source matrices of all other users, the source matrix of each user has a general beamforming structure. Simulation results demonstrate that the proposed iterative source and relay optimization algorithms perform much better than existing techniques in terms of both MSE and bit-error-rate.

Yuanwei Liu et al., (2016) non-orthogonal multiple access (NOMA) is applied to large-scale underlay cognitive radio (CR) networks with randomly deployed users. In order to characterize the performance of the considered network, new closed-form expressions of the outage probability are derived using stochasticgeometry. More importantly, by carrying out the diversity analysis, new insights are obtained under the two scenarios with different power constraints: 1) fixed transmit power of the primary transmitters (PTs), and 2) transmit power of the PTs being proportional to that of the secondary base station. For the first scenario, a diversity order of m is experienced at the m-th ordered NOMA user. For the second scenario, there is an asymptotic error floor for the outage probability. Simulation results are provided to verify the accuracy of the derived results. A pivotal conclusion is reached that by carefully designing target data rates and power allocation coefficients of users, NOMA can outperform conventional orthogonal multiple access in underlay CR networks.

Lu Lv; Jian Chen et al., (2016) here studies the application of non-orthogonal multiple access to a downlink cognitive radio (termed CR-NOMA) system. A new cooperative transmission scheme is proposed aimed at exploiting the inherent spatial diversity offered by the CR-NOMA system. The closed-form analytical results are developed to show that the cooperative transmission scheme gives better performance when more secondary users participate in relaying, which helps achieve the maximum diversity order at secondary user and a diversity order of two at primary user. The simulations are performed to validate the performance of the proposed scheme and the accuracy of the analytical results.

Fuhui Zhou et al., (2018) proposd explosive growth of mobile devices and the rapid increase of wideband wireless services call for advanced communication techniques that can achieve high spectral efficiency and meet the massive connectivity requirement. CR and NOMA are envisioned to be important solutions for fifth generation wireless networks. Integrating NOMA techniques into CRNs has tremendous potential to improve spectral efficiency and increase system capacity. However, there are many technical challenges due to the severe interference caused by using NOMA. Many efforts have been made to facilitate the application of NOMA into CRNs and to investigate the performance of CRNs with NOMA. This article aims to survey the latest research results along this direction. A taxonomy is devised to categorize the literature based on operation paradigms, enabling techniques, design objectives, and optimization characteristics. Moreover, the key challenges are outlined to provide guidelines for the domain researchers and designers to realize CRNs with NOMA. Finally, open issues are discussed.

Ming ZengDobre et al., (2017) presents Non-orthogonal multiple access (NOMA) is being considered as one of the promising radio access techniques for performance enhancement in 5G systems. Unlike conventional orthogonal multiple access (OMA), NOMA multiplexes users in the power domain, and employs successive interference cancellation (SIC) at the receivers of the users with better channel conditions. Recently, some work has been done to verify the superiority of NOMA over OMA. For example, the system-level evaluations show that NOMA improves both the capacity and cell-edge user throughput when compared with OMA. In this letter, the performance of non-orthogonal multiple access (NOMA) is compared with conventional orthogonal multiple access (OMA) over multiple-input multiple-output (MIMO) channels. It is proved analytically that for a simple scenario of two users, MIMO-NOMA dominates MIMO-OMA in terms of both sum rate and ergodic sum rate. Furthermore, for a more practical scenario of multiple users, with two users paired into a cluster and sharing a common transmit beamforming vector, the conclusion still holds. Numerical simulations are conducted, which corroborate the analytical findings.

III. PROPOSED SYSTEM

Implementation In this project investigate in order to support two different types of devices, two different (orthogonal) radio resource blocks (RBs) can be allocated. For each type of devices, a pool of preambles can be associated with an RB. This is the case to build two different access systems. One RB, a pool of preambles can be dynamically divided into two sub-pools of preambles to support two types of devices with different probabilities of preamble collisions. In this case, in order to have a sufficiently large number of preambles, a wide system bandwidth might be required, which may result in a low spectral efficiency. Notion of power-domain NOMA, design layered preambles with one RB to support different priorities between type-1 and type-2 devices with a high spectral efficiency in terms of the probability of preamble detection errors joint resource allocation problem involving the beamforming optimization and power allocation for the user-centric MIMO-NOMA IoT networks in order to maximize the system throughput.

Consider both the backhaul downlink (from the MBS to APs) and access downlink (from APs to devices) since the transmission rate of the access downlink is limited by the backhaul downlink. In the backhaul downlink, the MBS equipped with multiple antennas transmits signals to the single-antenna APs. The APs are grouped to serve devices, and the APs in the same AP group (APG) will share the same beamforming vector.

Consider a system that consists of a BS and a large number of devices that are synchronized for MTC. Suppose that a fraction of devices are active at a time and use random access to establish connections to transmit their data.

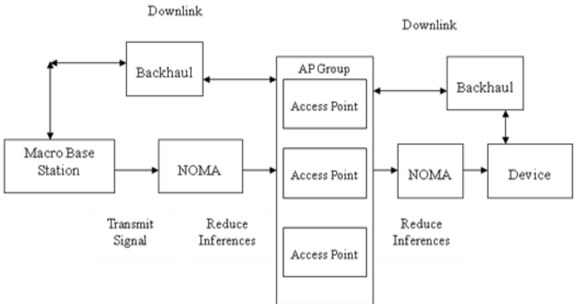


Fig. Proposed Block Diagram

3.2 DOWNLINK SIGNALS MODEL

In this subsection, we provide the signal model of the backhaul downlink model and access downlink respectively for the user-centric MIMO-NOMA IoT.

3.2.1 Backhaul Downlink Signal Model

As a forementioned, the MBS equipped with Nt antennas,and there are M single-antenna APs which are divided into N APGs. It is assumed that the number of APs in the nth APG is M_n, n=1,...,N. Obviously, N P n=1 Mn = M. Then, for the backhaul downlink, Mn APs in the nth APG shares the same beamformer, n=1,...,N, and N independent data streams can be given as

$$X=[x_1,x_2,...,x_N]^T \qquad (3.1)$$

The received signals of the APs can be written as

$$y = HWX + z \qquad (3.2)$$

In each APG, the NOMA is applied to reduce the interference caused by the beamformer sharing. In accordance with the principle of NOMA, the AP with better channel condition can decode the signals of the APs with weaker channel condition and then proceeds to subtract it from the received signal and decode its own data.

3.2.2 Access Downlink Signals Model

In this subsection, we give the signal model of the access downlink model of the user-centric MIMO-NOMA IoT networks. For the access downlink, there exists intra-APG interference as a result that multiple APs in the same APG transmit signals to the corresponding device simultaneously. For simplification, it is assumed that the inter-APG interference can be avoided due to the proper APs grouping and resource allocation.

$$y_n = \sum_{m_n=1}^{N_r} h_{m_n} \sqrt{p_{m_n} s_{m_n}} + z_{m_n} \qquad (3.3)$$

where h_{m_n} denotes the channel coefficient from the m_nth AP in the nth APG to the nth device; pmnn represents the transmit power of the m_nth AP in the nth APG to the nth device;

$$h_{1_n} \geq h_{2_n} \geq \cdots \geq z_{m_n} n \qquad (3.4)$$

According to the principle of NOMA, device n with SIC can successfully decode the signals of the APs with weaker channel condition. That is, the signal of the AP with best channel condition can be first decoded, however, it should experience interference from the other APs in the APG since the device cannot remove the signals from the other APs.

3.3 NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) TECHNOLOGY

Non-orthogonal multiple access (NOMA) technology has aroused a great concern in terms of enhancing spectrum efficiency. It allows multiple users allocated the same frequency block simultaneously. Users in the same resource block implement multiple access in the power domain through different power levels. At the transmitter NOMA actively introduces interference information. At the receiver, a user with a higher channel gain will be decoded first by using successive interference cancellation (SIC) technology, and the interference from co-subchannel users with lower channel gain can be eliminated directly.

We consider a cellular downlink NOMA transmission sys- tem in which the BS transmits the signals to a set of users denoted by $M = \{1,2,\ldots..M\}$. Both the BS and all users are equipped with the single antenna. The channel gain from the BS to the m-th user is. Without loss of generality, the users are assumed to be sorted such that $|h_M| \geq |h_2| \geq \cdots \geq |h_2|$. NOMA enables BS transmit signals on the same channel and serves multiple users simultaneously by using superposition coding techniques.

$$y_m = h_m \sum_{i\epsilon M} \sqrt{P_i S_i} + n_{m}, m\epsilon M \qquad (3.5)$$

The global optimal solution due to the non-convexity and NP-hard of the optimization problem. So we divide it into two processes so as to solve the problem more effectively. First, assuming that each subchannel is allocated equal power, we do a user-subchannel matching scheme by introducing equivalent channel gain. Then, based on the subchannels scheme that have been effectively matched, we focus our attention on power allocation and use the backward induction method to find the Stackleberg equilibrium point.

NOMA system, we should use the corresponding reward function in the utility function to represent the cache revenue earned by the system. Based on the above model, it is easy to observe that the SRRH utility function contains three parts: its own energy efficiency income, the interference payment to the reward revenue caused by the caching strategy. Hence, the utility of the MIMO-NOMA can be written as

$$U_n^S = \left(\lambda E_n^S - \sum_{k=1}^{k_s} \sum_{m_k=1}^{M_k} \left|h_{k,m_{k,n}}^{SM}\right|^2 \sum_{n_k=1}^{N_k} p_{k,n_{k,n}}^S\right) RC_n \qquad (3.6)$$

In the NOMA system, SIC technology is applied at the receivers to eliminate interference which is from other users on the same subchannel. For single cell network, with the channel response normalized by noise (CRNN) H k;i;n, jh, the decoding order of users decreases gradually. Therefore, we presume that N users are assigned to kth subchannel.

IV. RESULT AND DISCUSSION

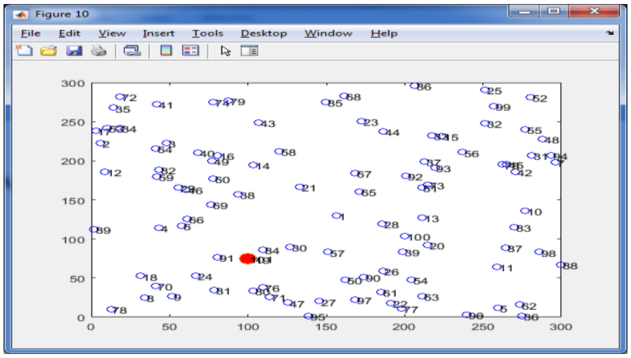


Fig 5.1 Node Creation

5.2 Model of AP and Device

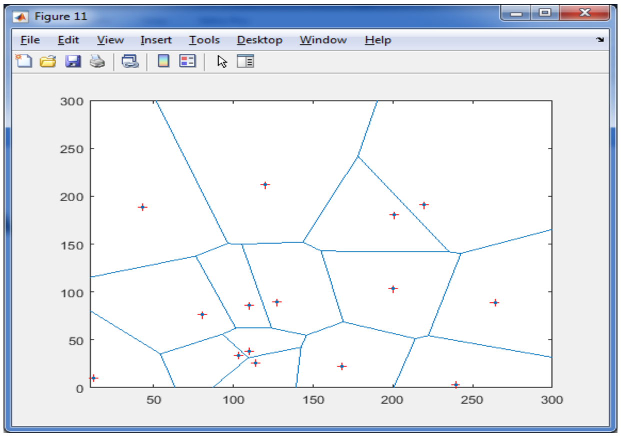


Fig 5.2 Model of AP and Device

5.3 Beam forming in the first cluster

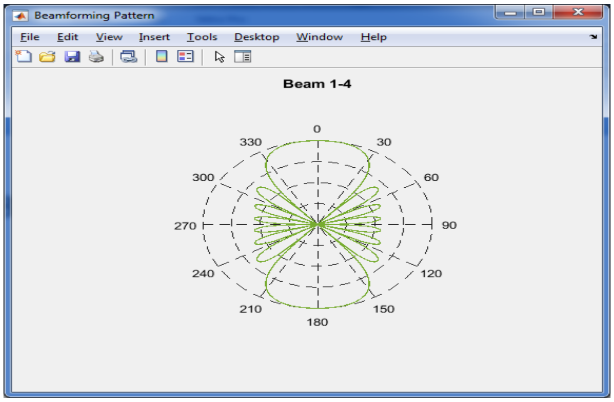


Fig 5.3 Beam forming in the first cluster

5.4 Beam forming in the second cluster

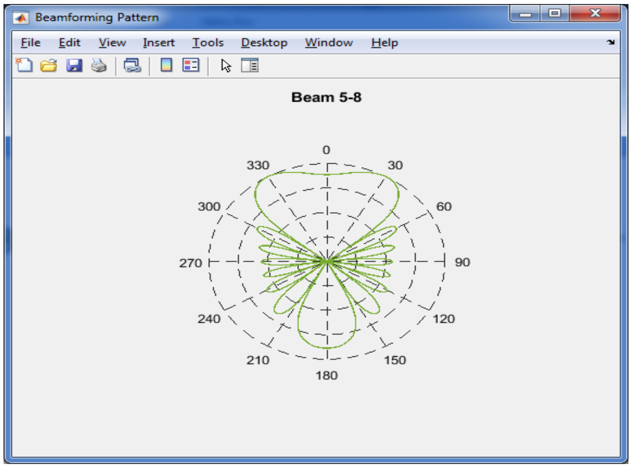


Fig. 5.4 Beam forming in the second cluster

5.5 Beam forming in the third cluster

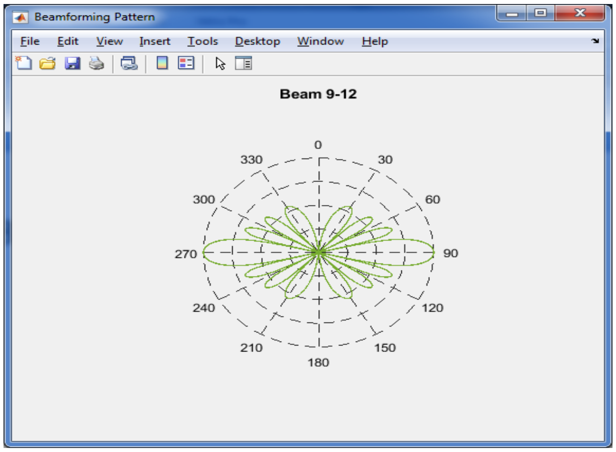


Fig. 5.5 Beam forming in the third cluster

5.6 Beam forming in the fourth cluster

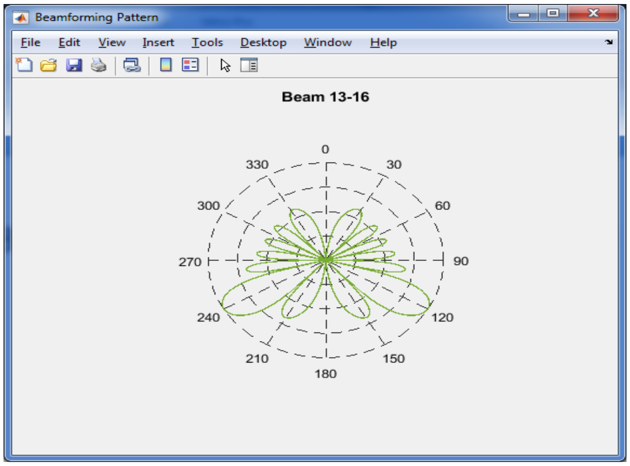
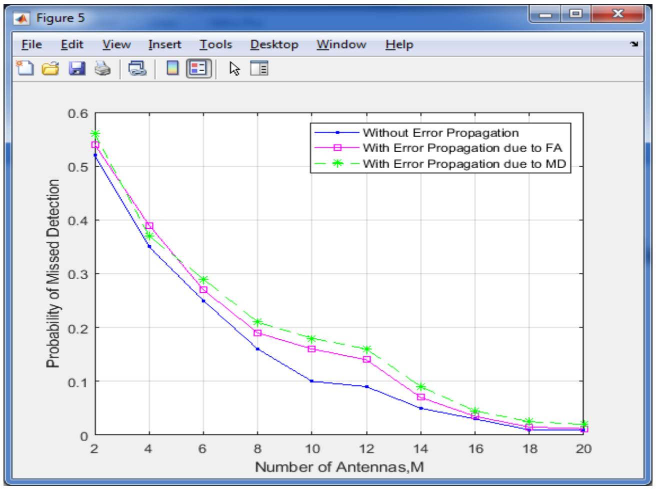


Fig. 5.6 Beam forming in the fourth cluster

5.7 Probabilities of active type-1 devices



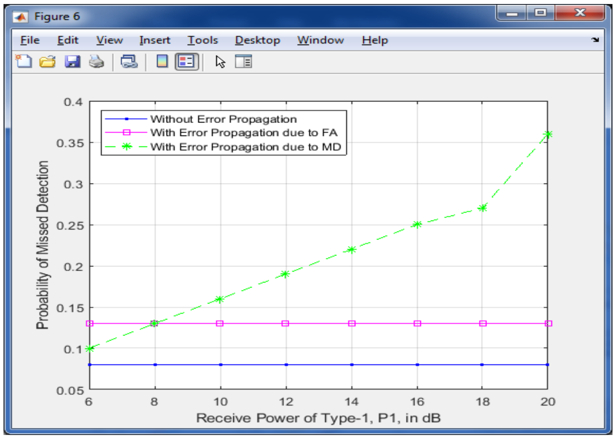


Fig 5.7 Probabilities of active type-1 devices

5.8 Probabilities of active type-2 devices

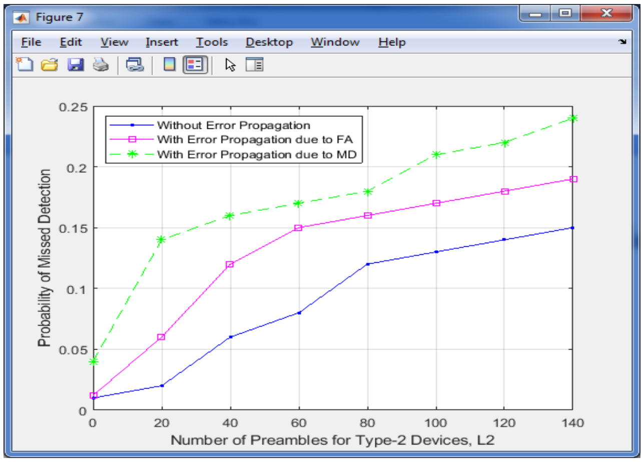


Fig 5.8 Probabilities of active type-2 devices

5.9 Throughput

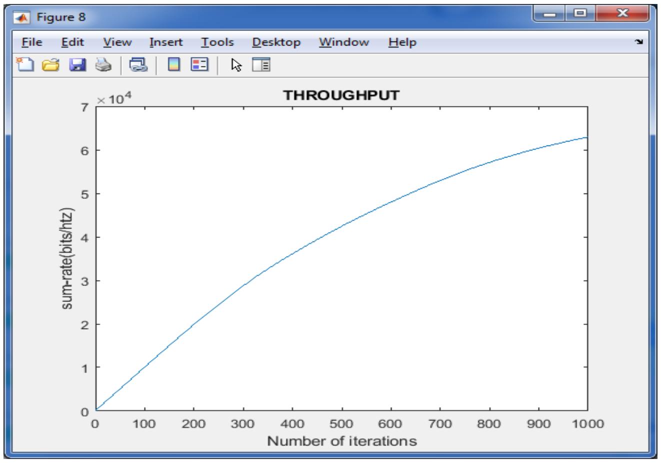


Fig 5.9 System Throughput

V. CONCLUSION

In this work have investigated the proposed RALP using the notion of power domain NOMA to support two different types of devices, namely type-1 devices and type2 devices with one RB for high spectral efficiency. Low-complexity detection methods have been studied to detect transmitted preambles. Thanks to the orthogonality of the preambles for type-1 devices, it was possible to find closed-form expressions for the probabilities of detection errors, which can be used to determine key parameters for target probabilities of errors. This has been an important feature as a certain performance guarantee can be ensured with known probabilities of errors for type-1 devices. Since mainly focused on RALP in terms of the performance of the physical layer, resource allocation and barring schemes with RALP are not studied, which would be the topics to be investigated in the future.

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